INTRA- AND INTEROBSERVER REPRODUCIBILITY IN OFF-LINE EXTRACTED CARDIAC TISSUE DOPPLER VELOCITY MEASUREMENTS AND DERIVED VARIABLES

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Abstract-**Aims: Using post-processing software it is possible to extract tissue velocities from colour-coded Doppler information in numerous positions in the myocardial wall. From velocity other variables such as displacement and deformation (strain) can be calculated. For adequate clinical assessment multiple measurements are needed. This is why reproducibility of the method must be evaluated.**
Methods: A moderately experienced observer measured systolic and diastolic basal velocity, displacement, strain rate and strain in right and left ventricular walls in 14 patients. The measurements were compared to those acquired by an experienced observer.
Results: The inter-observer variability for the systolic longitudinal and radial velocity was 6.9% and 12.0% for the right and 5.8% and 11.9% for the left ventricle respectively. The results with the least reproducibility were obtained for the radial strain rate where the inter-observer variability was 27.9% and 16.2% for the right and left ventricles respectively. Left ventricular velocity measurements had slightly better reproducibility than right ventricular. Derived calculations had a larger variation.
Conclusion: Basal velocity measurements and displacement calculations could be performed in the clinical routine by different observers with high reproducibility. Derived variables depending on multiple measuring locations could still be performed but with a method uncertainty of almost 15%.
***Keywords*–Reproducibility, Doppler, tissue velocity, strain, strain rate.**

I. INTRODUCTION

Extraction of velocity profiles from colour coded tissue Doppler images is a modality that has been developed during the last decade [1, 2]. Tissue Doppler measurement was first described by Isaaz et al. [3] and could at that time only be performed in one single spot during a heart cycle by using the high amplitude and low pass filtered information in an ordinary pulsed Doppler signal.

By using cross correlation technique instead of Fourier spectral analysis myocardial velocities could be extracted as colour information instead of velocity curves. It has always been said that colour velocity only measures mean velocity but by pulsed Doppler real maximal velocities could also be acquired. This is true when velocities in hydraulic fluids like blood are measured but of less importance when velocity of tissue compartments is evaluated as e.g. myocardial wall velocity where all muscle fibres are more or less glued together resulting in small differences between minimum and maximum velocities. The concept of extracting velocity profiles from colour information has the advantage that nearly an infinite number of spatial locations could be evaluated from one single acquired heart beat giving valuable information about spatial differences in velocity profiles without too much biological time dependant variation. Earlier studies of reproducibility in pulsed tissue Doppler recordings have shown that the reproducibility is better for cardiac long axis function than for short axis function [4]. In the same article reproducibility for anterior right ventricular wall measurements was unacceptably low and also diastolic measurements resulted in reproducibility levels which were unacceptable for the clinical routine. The reproducibility between different observers has been tested as a part of the MYDISE study [5] when using software for extracting velocity profiles from colour based raw data acquired cine-loops with simultaneous grey scale information. The results of that study showed good and acceptable values of reproducibility in measuring systolic velocities in basal and mid wall segments in apical projections. The results of apical segments were less satisfactory, but in the same study it is also shown that diagnosis of ischemic heart disease with high accuracy could be performed by using basal and mid segments only from apical projections. Those results were confirmed by [6]. The concept of using tissue Doppler for quantitative analysis of myocardial motion is superior to the very poor reproducibility achieved by just using eye-balling of grey scale information [7]. The goal of the present study is to perform intra- and inter-individual reproducibility calculations for all cardiac phases, not only systole but also diastolic measurements, and to evaluate the reproducibility of velocity based derived information like displacement, deformation (strain) and deformation velocity (strain-rate). The aim of this study was also to apply the reproducibility study to cine loops with high temporal resolution, which is extremely important to get true velocity information [8].

II. METHODOLOGY

A. Information aqcuisition

Cine loops containing an inter-foiled format for both grey scale and colour Doppler information were acquired with a temporal resolution of almost 100Hz with a GE-Vingmed system V and a 2.5 Mhz transducer. The cine loops were acquired both in parasternal long and short axis projections as well as in apical 2-and 4-chamber projections. The loops were acquired in 14 healthy individuals, age range of 20-65, and no previous history of heart disease.

Tissue Doppler sample volume was placed at the basal parts of the right and left ventricular wall (anterior, septal, lateral and inferior) in apical views to get the longitudinal

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velocities, and in the anterior and posterior walls at the papillary muscle level in parasternal short axis view in order to acquire the radial velocities.

The loops were transferred to personal computer with dedicated software (Echopac, GE Vingmed) for off-line analysis of tissue velocities and derived variables.

The study was approved by the local ethical committee.

B. Off-line analysis

The software could display both longitudinal and radial systolic as well as the diastolic velocities E-wave (Early diastolic wave) and A-wave (atrial diastolic wave).

Displacement (the integral of velocity) was calculated with computerised integration of velocity information. The maximal amplitude was then used as displacement excluding movements during the isovolumetric phases. Strain rate was calculated from identical positions using a sample distance between the arbitrary velocity points of 15 mm.

C. Statistical analysis

Coefficients of variability (CV) or error in a single measurement estimated from double measurements were calculated according to within-subject standard deviations formula for two different measurements by two observers without systematic errors. CV is the calculated by:

$$S_w = \frac{S_d}{\sqrt{2}} \tag{1}$$

where S_w is the common within-subject standard deviation and S_d the coefficient of variability, CV, can be calculated.

$$CV = \frac{S_w}{\bar{x}} \cdot 100\% \tag{2}$$

where x is the total mean of all measurements.

The data set was also analysed according to Bland Altman.

III. RESULTS

Examples of Bland Altman plots for the variations both inter- and intra observer are shown in fig. 1 and 2. All measured variables showed similar results. Note that the strain rate of fig. 2 has a higher CV than the velocities of fig. 1. This is representative for all strain rates and velocity measurements.

The inter- as well as the intra-observer variability for longitudinal systolic velocities was nearly equals as shown in table I, whereas the variation in radial velocity measured in short axis view were consistently higher. Integration of velocity to get displacement was an even more robust variable with a better Inter-observer variability 4.5%. The

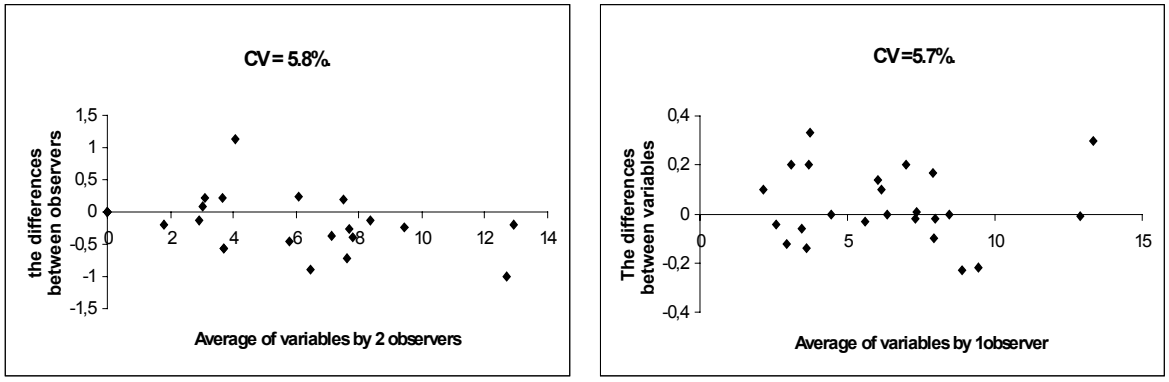

Fig. 1. Inter- and intra observer variability of measurements of the basal longitudinal systolic velocity in the left ventricle with values of coefficient of variation (CV). Inter-observer left and intra-observer right.

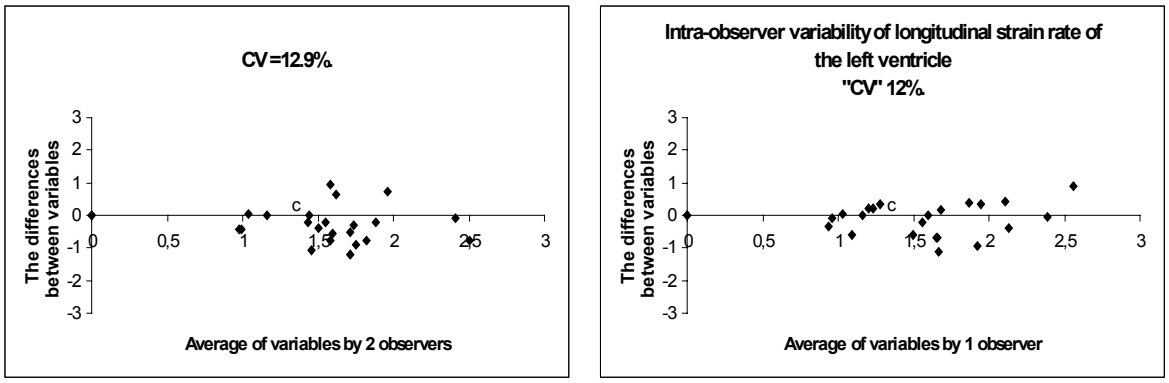

Fig. 2. Intra- and inter observer variability of measurements of longitudinal strain rate in the left ventricle with coefficients of variataion. Intra-observer left and intra-observer right.

TABLE I
THE MEAN VALUE OF ALL MEASUREMENTS IN EACH VENTRICULAR WALL OF THE CORRELATION COEFFICIENTS FOR INTRA- AND INTER OBSERVER (OBS.) VARIABILITY OF THE MEAN LONGITUDINAL (LONG.) AND RADIAL SYSTOLIC (SYS.) VELOCITIES (*v*), STRAIN RATES (SR) IN THE RIGHT AND LEFT VENTRICLE AND FOR THE E- AND A-WAVES AND THE AV-PLANE DISPLACEMENT (AV-DISPL.) OF THE LEFT VENTRICLE.

	Right ventricle				Left ventricle						
	Long. sys. *v*	Radial sys. *v*	Long. SR	Radial SR	Long. sys. *v*	Radial sys. *v*	E-wave	A-wave	AV-displ.	Long. SR	Radial SR
Intra-observer	6.2%	8.6%	13.8%	24.5%	5.7%	8.0%	9.6%	8.5%	5.2%	12.0%	13.9%
Inter-observer	6.9%	12.0%	14.9%	27.9%	5.8%	11.9%	10.2%	9.4%	4.5%	12.9%	16.2%

intra-observer variability in velocity measurements was similarly low in all walls of the left ventricle with a slightly better reproducibility for the septum where CV was found to be 4.5 %, in comparison to the CV of the lateral wall (5.2%), anterior wall (5.9%), inferior wall (5.7%) .

III. DISCUSSION

The inter-and intra-observer variability for both systolic and diastolic longitudinal velocities acquired by tissue Doppler technique were low, thus it is not crucial who performs the measurements as long as Doppler sample volume is placed at well defined points in the myocardial wall. For radial velocities the reproducibility shows some greater variation. This is even more pronounced for radial strain rate, which seems mainly to be due to difficulties in defining the exact points in short axis view and to the translation of the heart.

Strain rate seems to be not so well reproducible, as the calculation of strain rate requires measurement of velocity at two different points in that way it may increase the bias. Strain is the integral over time of the strain rates, and this operation may improve the result.

In comparison with other studies using the concept of colour extracted velocity information [5]. The reproducibility for velocity in the present study is slightly better because in the earlier reported study several centres with very different training in the method participated. In our study all measurements are performed with at least moderately trained observers. Anyhow the variation in both studies are below 10%.

The anterior wall is most difficult to register in apical projection and the expectance would be a higher variation in measurements than for the other walls. This is not the finding in the present study because the CV is comparable for all the ventricular walls.

As reported in earlier studies [9] the reproducibility for right ventricular measurements is a bit poorer than results for the left ventricle. Cardiac velocities are dependant on loading conditions [10]. The variation in loading condition between beats is probably bigger for the right ventricle and could induce a lower reproducibility when measurements is performed on cine-loops containing several beats.

The reproducibility with velocity curves extracted from colour is definitely better than pulsed wave Doppler measurements because performing such studies also include a component of biological variation because the area of measurement is located to only one point per heart cycle.

In conclusion tissue Doppler velocity curves calculated from colour images could be performed with high accuracy independent of observer. Strain rate measurements could be performed with acceptable variation.

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